RELATIONSHIP BETWEEN OUTRIGGER POSITION AND EXTERNAL COLUMNS SIZE IN MINIMIZING BUILDING RESPONSE TO WIND

ABDULKAREEM MUYIDEEN OLADIMEJI

A project report submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Civil - Structure)

FACULTY OF CIVIL ENGINEERING

UNIVERSITI TEKNOLOGI MALAYSIA

JUNE 2010

ACKNOWLEDGEMENT

I would like to acknowledge my supervisor, Dr. Roslida Abd. Samat, for the guidance and assistance she gave me in understanding the behaviour of tall building during the course of this thesis.

I also wish to express my sincere appreciation to my dad, Prof. Y.A. Abdulkareem and my entire family for the support given to me during my course of study at the University Teknologi Malaysia (UTM).

I am also grateful to Mr. Ibrahim Bamgbopa, Dr. Joseph Dodo and Mr. Zinas Bako for their efforts during my admission. I would like to thank all my friends, both at UTM and Nigeria for their moral support and understanding.

ABSTRACT

This research presents the relationship between the position of outrigger and the size of the external columns in minimizing the building responses to wind. Outrigger system has been one of the many structural systems in tall buildings used to reduce the building responses to wind load. The study on the usage of this system has been given little or no attention to the effect of the size of the external columns to the optimum position of outrigger. This research involves the position of the outrigger being varied and the responses: displacement and acceleration being computed. The procedure is repeated for each different size of the external columns. This analysis is carried out with the use of structural analysis computer software to determine the natural frequency of the building and Excel spreadsheet to determine the responses. The observations from the analysis will provide the conclusion on the relationship between the size of the external columns and the outrigger location with respect to the building response to wind.

Keywords: outrigger, wind, column size, tall building, building response.

ABSTRAK

Penelitian ini menyajikan hubungan antara kedudukan cadik dan saiz medan luaran dalam meminimumkan tanggapan bangunan untuk angin. sistem outrigger telah menjadi salah satu sistem struktur bangunan tinggi banyak digunakan untuk mengurangkan tanggapan bangunan untuk beban angin. Kajian mengenai penggunaan sistem ini telah diberikan sedikit atau tidak ada perhatian pada pengaruh saiz medan luaran ke kedudukan optimum outrigger. Penyelidikan ini melibatkan kedudukan outrigger yang sedang bervariasi dan respons perpindahan dan percepatan sedang dikira. Prosedur ini diulang untuk setiap saiz yang berbeza dari medan luaran. Analisis ini dilakukan dengan menggunakan perisian komputer analisis struktur untuk menentukan frekuensi alami bangunan dan spreadsheet Excel untuk menentukan jawapan.Pengamatan dari analisis tersebut akan memberikan kesimpulan tentang hubungan antara saiz medan luaran dan lokasi outrigger berhubung

Kata kunci: outrigger, angin, saiz medan, bangunan tinggi, bangunan respon.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

b	-	breadth
	-	mean hourly wind speed factor
	-	3-sec gust speed factor
C	-	turbulence intensity factor
C_{fx}	-	mean along-wind force co-efficient
D	-	diameter of building
E	-	modulus of elasticity
f	-	frequency of vortex shedding
G_f	-	gust factor
g_p	-	peak factor
g_Q	-	peak factor for resonant response
g_R	-	peak factor for resonant response
g_V	-	peak factor for resonant response
h	-	height
I	-	moment of inertia

I^{-}	-	intensity of turbulence
K	-	wind directionality factor
L	-	length
L^{-}	-	integral length scale of turbulence
ℓ	-	integral length scale factor
m_1	-	modal mass
m_{eff}	-	effective mass
N_1	-	reduced fequency
n_1	-	building natural frequency
$\emptyset(\ )$	−	fundamental modal shape
$\ddot{}(\ )$	−	rms along − wind acceleration
P	-	applied load
ρ	-	air density
Q	-	background response factor
R	-	resonant excitation
R_B, R_h, R_L	-	values from Eq 6-13
R_ℓ	-	reduction facrtor
r	-	roughness factor
S	-	stroudal number
S_g	-	gust speed
S_m	-	mean speed
T	-	length of time – 3600s
t	-	thickness

μ(z)	-	mass per unit height
V	-	3 sec gust speed at height ‾
Vol	-	volume
-	−	3 sec h h $(\frac{\hat{}}{33})h$ =
X(maz)(z)	-	maximum along-wind displacement
y	-	deflection
z	-	height above ground level
‾	-	equivalent height of structure
α	-	3-sec gust speed power law exponent
	-	mean hourly wind speed power law
	-	reciprocal of α
□	-	mode exponent
∈	-	integral length scale power law exponent
	-	mode exponent
	-	natural frequency of vibration

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Wind effects on tall buildings have been a major determinant in the architecture and design of such buildings. Several structural systems have been developed and incorporated in many tall buildings to control and reduce the response of these buildings to the lateral loads caused by wind.

The acceptable drift limit (top deflection in tall building) according to the Malaysian Code (M.S 1553:2002) is 1/500 of the building height. The ASCE7-02 states that the drift limit is 1/400 of the building height (ASCE Task Committee on Drift Control, 1988). The acceleration is also an important factor of the drift that brings about the feel of the building drift (motion) to human notice. A building response of acceleration up to $0.5 m/s^2$ causes difficulty to walk naturally and also to lose balance when standing at the top of such buildings (Yamada and Goto, 1975).

The use of core-wall system has been a very effective and efficient structural system used in reducing these responses due to lateral load. But when the building is taller than 500ft (152.4m), the core does not have the adequate stiffness to keep the wind drift down to acceptable limits.

A structural system known as outrigger system is added to this tall building. This outrigger system consists of a deep horizontal cantilever beam connecting the main core of the building to the outer (exterior) columns. This outrigger helps in tying-down the exterior columns to the core wall. Here the column double functions as gravity loads support and also as a restraint to the lateral movement of the core. The movement of the core is reduced as compared to a free-standing core alone resisting the lateral loads. The restrain introduces a point of inflection in the deflection curve thus reducing the lateral movement at the top. The stiffness created by the inclusion of the outrigger is increased up to 25 to 30 percent of the original structure without the outrigger in place (Taranath, 1988).

Wu and Li in 2003 suggested that the location of outriggers should be as near as possible to the building foundation in order to reduce the base moment in the core. Samat, Ali and Marsono in 2008 stated that the optimum location to construct the outrigger is between the one-quarter to the two-third of the height of the building to minimize the wind responses of the building.

The exterior columns acting as a tie-down of the core is definitely of great importance to the entire system to function properly. The size of these exterior columns will have a great impact in the degree of the stiffness required for the system to perform. To this, the size of the exterior columns will play a vital role in affecting the best location of the outrigger to minimize the building's response to wind.

1.2 Problem statement

The use of outrigger-braced system is gaining more widely acceptance as a structural system to reduce drift in tall buildings. This system contains three main elements, i.e. deep outrigger beam, the core wall and the exterior (external) columns. The performance of this system has been proven to be influenced by the size of the core wall and location of the outrigger beam (Samat, Ali and Marsono. 2008). Presently, the relationship between the size of the external columns and the optimum position of the outrigger is not known. Therefore to find this relationship, a 64 stories building, each story with a height of 4.5m, will be considered with several positions of outrigger for each different column size.

1.3 Hypotheses

It can be guessed that the drift of the tall building will be decreased with an increment of the column size to a specific size having the position of the outrigger beam being changed. The decrement in wind response will reach a minimum at a certain position of the outrigger, for each size of external column used.

1.4 Objective of study

The objectives of this study are as follows:

i. To investigate the effect of the external column size to the optimum position of the outrigger in tall building to minimize the wind response (acceleration and displacement).

ii. To suggest the optimum column size for any position of the outrigger in tall building to get the minimum wind drift response.

1.5 Scope of study

The scope of this work will focus on the wind response of tall building with regards to the external column sizes and outrigger positions. A building with a square plan of 48m x 48m with a height of 288m is used for the model. Here, the column size and outrigger position are being varied and the response of the building being computed.

1.6 Significance of study

The response to wind by tall buildings which are outrigger-braced is influenced by the position of the outrigger. In this study, computer model analysis together with computation of responses by a program written is used to investigate how the size of the exterior columns influences the optimum position of the outrigger. This study will help dictate the appropriate positioning of the outrigger beam for a particular column size and vice versa in order to get an optimum response. The application of a particular outrigger position for a particular external column size and vice versa can be comprehensive and recommended for the engineers in the construction industry for the construction of tall buildings. This will also help in saving time, materials and labor costs.

REFERENCES

1) Taranath, B. S. (1988) Structural Analysis and Design of Tall Buildings. *McGraw-Hill Book Company, New York.*

2) Smith, B. S., Coull, A. Tall Building Structures: Analysis and Design. *John Wiley and Sons, Inc, New York.*

3) Mendis, P., Ngo, T., Haritos, N., Hira, A., Somali, B., Cheung, J., (2007). Wind loading on Tall Buildings. *Journal of Structural Engineers, Special Issue*.

4) Lam, K., Leung, M. Y. H., Zhao, J. G., (2008). Interference effect on Wind Loading of a Row of Closely Spaced Tall Buildings. *Journal of Wind Engineering and Industrial Aerodynamics*, pages 562-583

5) Pan, L. B., Liu, P.C., Bakoss, S.L. (1993). Long-Term Shortening of Concrete Columns in Tall Buildings. *Journal of Structural Engineers*.

6) Nair, R. S., (1998). Belt Trusses and Basements as "Virtual" Outriggers for Tall Buildings. *Engineering Journals*.

7) Samat, A. R., Ali, N.M., Marsono, A. K., (2008). The Optimum Location of Outrigger in Reducing the Along-wind and Across-Wind Responses of Tall Buildings. *Malaysian Journal of Civil Engineers*.

8) Kian, P. S., Siahaan, F. T., (2001). Use of Outriggers and Belt Truss System for High-Rise Concrete Buildings. *Dimensi Teknik Sipil*.

9) Wu, J. R., Li Q.S., (2003). Structural Performance of Multi-Outrigger-Braced Tall Buildings, *Journal of Structural Design of Tall and Special Buildings*.

10) Ziedabadi N. A., Mirtalae K., Mobasher B., (2004). Optimised Use of the Outrigger System to Stiffen the Coupled Shear Wall in Tall Buildings. *Journal of Tall and Special Buildings.*

11) Hoenderkamp, J. C. D., (2008). Second Outrigger at Optimum Location on High-Rise Shear Wall. *Journal of Tall and Special Buildings.*

12) ASCE 7-05, Minimum Design Loads for Buildings and Other Structures.

13) Smith, R. J., Willford M. R., (2007). Damped Outrigger Concept for Tall Buildings. *Journal of the Structural Design of Tall and Special Buildings*, pages 501-517.

14) Abdel-Rohman, M., Leiphilz H.H., (1983). Active Control of Tall Buildings. *Journal of Structural Engineers*, Vol. 109, No 3.

15) Irwin, P., (2009). Wind Engineering Challenges of the New Generation of Super-Tall Buildings. *Journal of Wind and Industrial Aerodynamics*.

16) Davenport, A. G., (1967). Gust Loading factors. *Journal of Structural Division*, ASCE.

17) Vickery, B. J., (1966). On the Assessment of Wind Effects on Elastic Structures. *Civil Engineer Translational Institute of Engineers*.

18) Coull, A., Lau, W. H. O., (1989). Analysis of Multi-Outrigger-Braced Structures. *Journal of Structural Engineers.*

19) Bennetts, I. D., (1995). Structural Systems for Tall Buildings. Council on Tall Buildings and Urban Habitat.

20) Torkamani, M. A. M., Pramono, E., (1985). Dynamic Response of Tall Buildings to Wind Excitation. *Journal of Structural Engineers*.

21) Kijewski-Correa, T., Pirnia, J.D., (2007). Dynamic Behaviour of Tall Buildings Under Wind: Insights From Full-Scale Monitoring. *Journal of the Structural Design of Tall and Special Buildings*, pages 471-486.

22) Chang, J. C., Soong, T. T, (1980). Structural Control Using Active Tuned Mass Dampers. *Journal of the Engineering Mechanics Division,* ASCE, Vol. 106.

23) Fintal, M., Khan, F. R. (1971). Effects of Column Creep and Shrinkage in Tall Structures: Analysis for differential Shortening of Columns and Field Observations of Structures. *American Concrete Institute*.

24) Yamada, M., Goto, T. (1975). The Criterion to Motion in Tall Buildings. *Proc. Pan-Pacific Tall Buildings Conference, Hawaii*. pages 233-244

25) Malaysian Standard on Code of Practice on Wind Loading for building Structure, Kuala Lumpur, MS 1553:2002.

26) http://aerodata.ce.nd.edu/, *NatHaz (Natural Hazards) Modeling Laboratory University of Notre Dame aerodynamic data base*

27) Charles, H., Udom, H., Leonard, M., Design of the World's Tallest Buildings-Petronas Twin Tower at Kuala Lumpur City Centre.